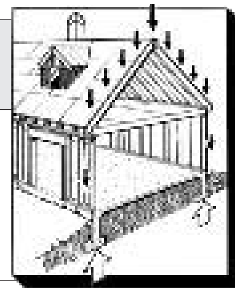

Concrete and Steel: An Effective Partnership

by Harris Hyman, P.E.

Rebar in concrete foundation walls is among the more misunderstood aspects of light construction. Most builders have a pretty good feel for the strength of framed walls and floors, but their intuition deserts them when it comes to the foundation. In consequence, there is a lot of folklore about what works and what doesn't.

Let's start with fundamentals. The strength of concrete is in compression — it easily resists direct crushing loads. However, this marvelous quality is offset by an extremely low strength in tension, which gives concrete a tendency to crack in service.

Concrete, depending on the mix, will take a 2,500- to 8,000-pound-per-square-inch load in compression. But in tension, concrete will resist only about 250 to 350 pounds per square inch before it starts to crack. So to give concrete some tensile strength, we insert a little steel — enough to give it the necessary strength, but not enough to push the cost out of sight.

The main way we add steel is in the form of rebar, round steel rods that have the surface knotted up so that the concrete can bond to the steel. Working together, the steel handles the tension and the concrete handles the compressive load. It's a very effective partnership.

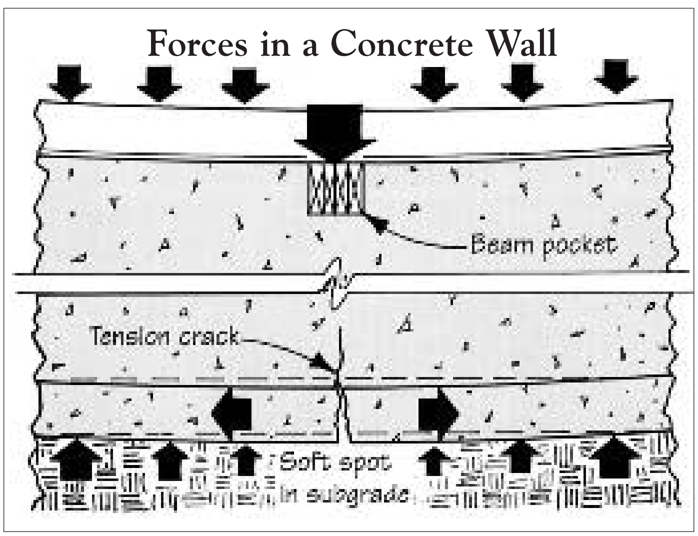

Figure 1. *The weight of a building on a poured foundation mainly puts the concrete in compression, which it can easily handle. But uneven or concentrated forces — from a soft spot in the subgrade or a point load on the wall — create stresses that can lead to tensile cracking at the bottom of the wall. Reinforcing steel prevents these cracks from spreading.*

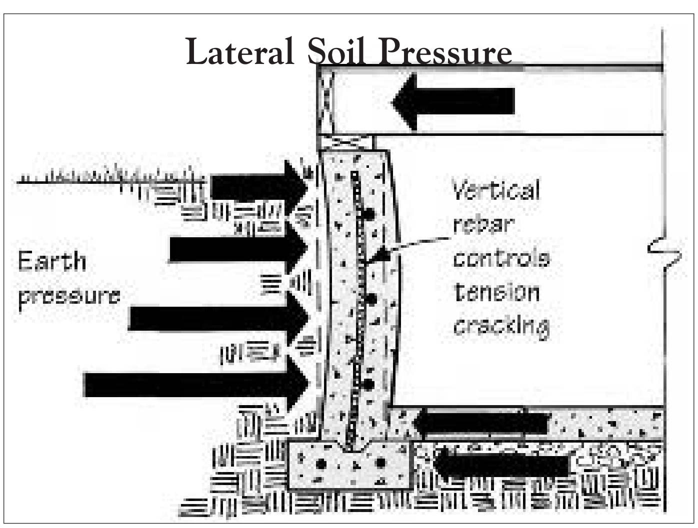

Figure 2. *In all but the sandiest soils, the pressure of the earth can bow and crack a concrete foundation wall. Vertical rebar strengthens the wall and prevents cracks from developing on the inner face.*

There are three areas where rebar is quite important: to help control settlement cracking from the weight of the house, to resist the lateral pressure of the earth against the foundation walls, and to help resist lateral forces from wind and earthquakes that are transferred to the foundation. Let's look at each of these separately.

Settlement

The most obvious load on a foundation is the weight of the building. A 24x40-foot wood frame house will typically weigh in somewhere between 90,000 and 130,000 pounds. For this discussion, let's call it 110,000 pounds. The perimeter of the foundation is 128 feet, and at 8 inches thick, has 12,032 square inches of bearing area. This is only 9 pounds per square inch, and the typical unspecified batch concrete has a design capacity of 3,500 psi. Not really too much to worry about in compressive strength. The problems must be elsewhere.

The concrete foundation transfers the load of the house to undisturbed soil, which has the capacity (in most cases) to match the weight of the house. But many soils do not have an even, smooth structure. There are usually hard spots, which have full bearing capacity, interspersed with soft spots — areas with voids that have little bearing capacity. The foundation bridges the soft spots in the soil, carrying the load to the hard spots. But this sort of loading creates shear stress in the concrete (see Figure 1), which can cause it to crack. The problem can be aggravated by concentrated loads, such as might occur where a bearing wall or girder meets the exterior wall.

To control the cracking, I suggest a grid of #4 bars about 24 inches on-center for the horizontal bars and 48 inches on-center for the vertical bars. (Incidentally, the number of the bar is the diameter in eighths of an inch: #3 is $^{3}/_{8}$-inch diameter, #4 is $^{1}/_{2}$ inch, etc.) When a settlement crack reaches a steel bar, it stops and does not carry vertically through the foundation.

Foundation walls are usually placed on footings. The stresses in the footing are quite light, but following the thinking on cracking, I (and most contractors) use two #4 bars in every footing.

Seismic Hold-Down Detail

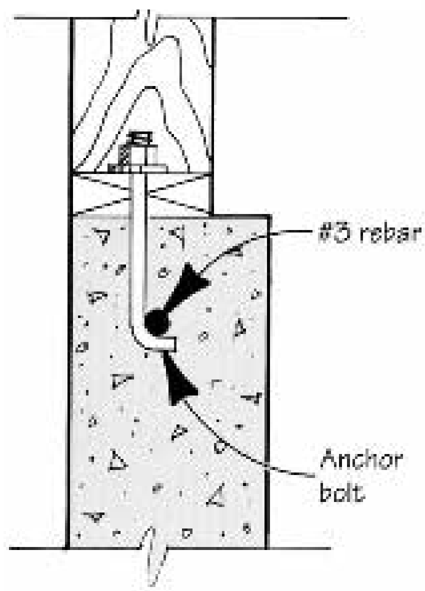

Figure 3. *Some seismic codes now require that foundation anchors be looped around lengths of #3 rebar to prevent them from ripping loose in severe earthquakes.*

Lateral Earth Pressure

Another load on the foundation wall comes from the pressure of the earth on the basement wall. In this situation the wall acts like a vertical beam, with a load from the side (Figure 2, previous page). This is a problem in areas with soft clay soils, especially those areas prone to nasty freeze/thaw cycles. In these regions, rebar is essential for preventing serious, unsightly foundation cracks (although the building will rarely fail big time). Walls up to 4 feet high aren't really affected. But in walls 4 to 8 feet in height, the CABO code calls for #3 vertical bars 18 inches on-center for adequate lateral strength.

Wind and Seismic Forces

Recent earthquakes in Oregon and California suggest that buildings need lots of lateral bracing to resist side-to-side forces from the moving earth. This lateral bracing must be tied down to the foundation. The sills and shear panels are anchored to the concrete with ordinary L-type anchor bolts or a variety of patented anchors. The concrete foundation must prevent these anchors from ripping loose, and to do this, recent codes (and good sense) call for a pair of horizontal #3 bars about 6 inches below the top of the wall (Figure 3). The anchor bolts or straps are looped around these bars, which spreads the load along the wall.

Adequate anchoring is also appropriate in windy areas, where gusts can jar the houses off the foundations. It is prudent (and fairly inexpensive) to tie structures down in hurricane and tornado regions.

Recommendations

So for most typical 8-foot poured foundation walls, I recommend at least a 24x48-inch grid of #4 bars in the wall and two #4 bars in the footing. For our 24x40-foot home, this is about $600 in steel and labor to do the job. I think that's enough steel for good service in most situations, but not an excessive (and needlessly expensive) amount.

But I'm sure this looks like a *lot* of steel to many builders — those who never use rebar or who use only a little. In fact, depending on where you build, it might be a lot. If the soil in your area has an even texture, is stable, and drains well — like sandy or gravelly soils — then there may be no soft spots, no frost action, and no cracking to control. In such places, omitting the steel is a time-honored practice that works well. The codes recognize this and allow for "plain" (unreinforced) concrete foundations a minimum of 8 inches thick and extending no more than 7 feet below grade.

There are other regions, however, where standard practice is to use only a couple of bars. This is *not* a good idea. If the neighborhood soil allows you to skip reinforcing, why bother with it at all? If you are going to use steel at all, there should be enough to do a job. My suggestion is a *minimum*. Any less steel is just decoration — it doesn't do any work.

Other Details

There are some detail items with reinforcing steel that deserve attention.

Concrete coverage. "Coverage" is the amount of concrete that surrounds the steel. For #4 bar, coverage should be at least 1 1/2 inches for exposed concrete. For footings and pads resting on the soil, 3 inches is required. When the steel is too close to the surface, there is not enough concrete to cling to the rebar, and the steel does not bond properly, losing the tension/compression partnership of steel and concrete. Exposed surfaces where the steel is not deep enough also tend to spall and flake off after a few seasons.

Splicing. Where bars are not long enough, they must be spliced, and there are at least three ways to do this: welding, mechanical splices, and overlaps. Welding and patented mechanical fasteners are expensive for a light frame building foundation, so most builders overlap the bars by 12 inches (code calls for 24 diameters of overlap) and tie them together with wire. You don't need much wire, just enough to hold the bars in place. The real work is done by the overlapping bonds between the steel and concrete, not the little pieces of wire.

Point loads. A common necessity in light construction is a pad for a concentrated load, such as a post might carry. As an example, for a load of 6,000 pounds on 1,500-psf soil, use a 24x24 pad 8 inches thick with #4 bars 8 inches on-center. Here, the steel must *not* be left out.

When to Call Your Engineer

I'll close with some limits on this discussion. You need some special engineering in (at least) these situations:

- Squishy soils that will not accept a 1,000-psf load
- Walls over 8 feet in height
- Retaining walls over 4 feet high
- Concentrated loads over 6,000 pounds
- Unusual loads like vehicles or machinery
- Buildings over three stories tall
- Masonry buildings
- Seismic Zones 3 and 4
- High-wind coastal zones

So, while you don't have to put in excessive reinforcement, don't stint on the steel. A couple of months back I had to go out to check a foundation built without reinforcement. My bill would have paid for a substantial amount of the steel, not to mention the contractor's time in fussing with the matter, and the ill will and aggravation of the county code enforcement officer. ■

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